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DISCLAIMER

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RECONDITIONING CONTAMINATED GRAVEL

ABSTRACT

Lawrence Livermore National Laboratory (LLNL) has developed a portable screening system that will recondition radioactively contaminated gravel in the field. The separation technique employed by this system removes dirt, contaminated debris, and other fine particles from gravel. The separation process can be used on gravel or other comparable material ranging in size up to 2.5-cm (1-in.) in diameter. The particle size of dirt and debris removed is variable. For pea gravel, the particles removed can vary from 38 µm–1 cm (3/8-in.).

At LLNL, gravel is used in conjunction with the experimental testing of explosives to reduce shock wave propagation. The gravel surrounds the experimental device and buffers the energy generated from the explosion. During an explosion, some of the gravel is broken down into small particles and mixed with contaminants. Contaminants in the used gravel originate from metal sheathing and other parts comprising the experimental device. These contaminants may consist of radionuclides (primarily depleted uranium) and metals (e.g., beryllium, copper, and zinc) that are considered hazardous by the State of California when disposed. The small particles generated during the explosion mix with the gravel and collect in the void space between the gravel. Loss of void space increases the aggregate material compressive strength and reduces the gravel's effectiveness for shock wave reduction. Reconditioning removes the small particles and some contaminants and restores the gravel's effectiveness for shock wave reduction.

This paper describes the process that conveys contaminated material into the screener system, sprays the material with recycled water or other mild cleaning chemicals, and separates particles based on size. Particles greater than a specified size are discharged out of the screener separator and recycled back into use, thereby reducing the amount of mixed waste generated and minimizing the need for new gravel. An array of smaller particles are discharged into drums and, if desired, reused in other applications. The fines or silt are flushed out of the separator with the water and are removed from the water and consolidated into a drum with the use of a hydrocyclone separator and drum decant system. Because the water in the spray system is recycled, minimal makeup water is needed. The system monitors pH and total dissolved solids (TDS) and, when undesired levels of pH or TDS are reached or when suspended solids could result in clogs, the spray system can be purged and refilled.

INTRODUCTION

Lawrence Livermore National Laboratory performs experimental testing of explosives at designated remote locations in an area called Site 300. An experimental device is used for the explosive test. The construction of the experimental device varies, but it usually has a metal sheath and often contains depleted uranium, beryllium, copper, and zinc. Experimental devices can also contain lead. The experimental testing at Site 300 is conducted on gravel pads. The gravel on the pad is approximately 1.3 cm (0.5 in.) in diameter, with the smallest particles being 2 mm in diameter. The gravel is used to reduce shock wave propagation during explosive testing.

The experimental device is buried with gravel, which surrounds it and buffers the energy generated from the explosion. During the explosion, the gravel is broken down into smaller particles and mixes with contaminants. Contaminants in the used gravel originate from metal sheathing and other parts comprising the experimental device. These contaminants may consist of radionuclides (primarily depleted uranium) and metals (e.g., beryllium, copper, zinc) that the State of California considers hazardous to dispose of.

After an explosive test, a higher percentage of the gravel material is 2 mm or smaller. These small particles generated during the explosion mix with the gravel and reduce its effectiveness for shock wave reduction. With repeated use of the gravel, a buildup of contaminants and radioactivity is deposited on the gravel. When the contaminants are beryllium, copper, and zinc, the buildup results in the potential generation of low-level radioactive waste with California hazardous metals. When the contaminants are lead and chromium, the buildup results in the potential generation of Resource Conservation and Recovery Act (RCRA) mixed waste. See Table 1 for a listing of the state and federal regulated hazardous metals and their regulatory levels. To avoid the possibility of generating mixed waste after it is used, the gravel must be removed from the pad and either discarded or reconditioned.

To determine whether or not a waste is hazardous, the State of California requires a leach test and/or a total waste analysis using the California Assessment Manual Wet Extraction Test (CAM-WET) for Soluble Threshold Limit Concentration (STLC) and for Total Threshold Limit Concentration (TTLC). The STLC is a extraction method that measures the amount of extractable substances in the material. The TTLC provides a total analysis of the material by determining which analytes are present and their concentrations. These tests are used instead of the federal Toxicity Characteristic Leaching Procedure (TCLP).

Before we developed the gravel reconditioning method, the gravel was removed from the gravel pad when it no longer reduced shock waves effectively and was placed into disposal containers, sampled, and analyzed. Depending on the analysis, the waste was disposed of as low-level radioactive waste or low-level radioactive waste with California hazardous metals. The contamination had not built-up enough to consider the waste RCRA mixed waste. The amount of gravel removed averaged around 4,536 kg (10,000 lb) per explosive test, and about 4,536 kg (10,000 lb) of clean makeup gravel was added to replenish the pad.

Using our reconditioning method, the small particles (particles less than 2 mm) and some contamination are removed from the gravel. Now, up to 90% of the gravel (4,082 kg or 9,000 lb per test) is reconditioned and placed back into use. About 454 kg (1,000 lb) of clean makeup gravel is needed to replenish the pad after an explosive test.

TREATABILITY STUDIES

We performed small-scale treatability studies to determine if screening would be an effective way of reconditioning gravel. A multitiered bench-top sieve unit (or screener) with an assortment of screen mesh sizes was used in the experiments.

Table 1. Metal Constituents, Regulatory Levels, and Characteristic Codes.

Metals Leached	State Regulatory Levels		Federal Regulatory Levels	Characteristic EPA[1] Code
	STLC (mg/l)	TTLC (mg/kg)	TCLP (mg/l)	
Antimony	15	500	–	–
Arsenic	5.0	500	5.0	D004
Barium	100	10,000[2]	100.0	D005
Beryllium	0.75	75	–	–
Cadmium	1.0	100	1.0	D006
Chromium (VI)	5	500	5.0	D007
Cobalt	80	8,000	–	–
Copper	25	2,500	–	–
Lead	5.0	1,000	5.0	D008
Mercury	0.2	20	0.2	D009
Molybdenum	350	3,500	–	–
Nickel	20	2,000	–	–
Selenium	1.0	100	1.0	D010
Silver	5	500	5.0	D011
Thallium	7.0	700	–	–
Vanadium	24	2,400	–	–
Zinc	250	5,000	–	–

1 EPA = Environmental Protection Agency
2 Excluding barium sulfate

Dry Screening

The first experiment was performed on dry gravel to determine the particle distribution of the gravel so that we could determine the optimal screen size(s) for retaining undersized particles. Six screens were selected with the sieve mesh ranging from 8 to 400 (i.e., sieve openings ranging from 2.8 mm to 0.037 mm). Approximately 1,600 g of dirty gravel was added to the top tray and allowed to shake in the sieve unit for 10 minutes. After shaking, the amount of gravel in each tray and in the bottom of the pan was calculated. See Table 2 for results of the test.

The design for the gravel reconditioning process made use of two screens: one screen for removing coarse fines from the gravel and the other for removing silt and small fines from the coarse material. Table 2 indicates that particles less than 2 mm account for 4.1% of the total gravel. When using a screen with a larger opening (i.e., No. 8 mesh), only a small increase of particles was noted, so we determined that No. 10 mesh screen could adequately remove coarse fines from the gravel. Both the No. 200 mesh and No. 325

mesh screens could adequately remove silt and small fines from the coarse material; however, the No. 325 mesh screen is constructed of fine wires and is very fragile. Because the No. 325 mesh screen tears easily and is expensive ($300 compared to $186) to replace, we decided to use the No. 200 mesh screen.

Table 2. Particle Distribution With Various Sieves.
(Sample Weight: 1,608.9 g)

Sieve Mesh No.	Sieve Mesh Opening (mm)	Range of Particles (mm)	Weight of Retained Gravel (g)	Weight Fraction (%)
8	2.38	≥ 2.38	1,531.4	95.2
10	2.00	< 2.38 and ≥ 2.00	10.3	0.6
40	0.42	< 2.00 and ≥ 0.42	29.5	1.8
200	0.74	< 0.42 and ≥ 0.74	23.1	1.4
325	0.044	< 0.74 and ≥ 0.044	4.8	0.3
400	0.037	< 0.044 and ≥ 0.037	2.1	0.1
bottom of pan	< 0.037	< 0.037	7.3	0.5

Wet Screening

In the second experiment, we tested wet gravel to determine the effectiveness of spraying the gravel with water while screening and calculated the moisture content of the wet gravel removed from the unit. The sieve unit was adapted with a recirculating water system. The test was scaled down from the assumptions that the gravel will be fed at a rate of 907 kg/h (2,000 lb/h), the water flow rate will be twice the mass flow rate of gravel or 30.3 L/min (8 gal/min), and the screener will have an estimated sieve diameter of 1.2 m (48 in.). The bench scale test was performed with 1.8 kg (4 lb) of gravel, 3.6 L (0.96 gal) of water, using a water recirculation rate of 0.83 L/min (0.22 gal/min), and on the sieve unit that has a 20.3 cm (8 in.) sieve diameter. Only two trays (No. 10 mesh and No. 200 mesh screens) were added to the sieve unit. The dirty gravel was added into the top tray (No. 10 mesh screen) of the sieve unit, the water recirculation system was turned on, and the unit was allowed to shake 4.32 minutes. After shaking, the amount of gravel was calculated in each tray and for the bottom of the pan. See Table 3 for the wet screening results.

Table 3 indicates that particles less than 2 mm account for 9.6% of the total gravel. Compared to dry screening (where particles less than 2 mm account for 4.1% of the total gravel), we determined that wet screening is more effective at removing smaller particles from the gravel. In addition, the amount of water removed from the system when the gravel is discharged is small. The water makeup rate for both the top tray and middle tray of the wet gravel is 3.8%.

Table 3. Particle Distribution and Moisture Content of Wet Gravel.
(Weight of Dry Gravel Before Testing: 1,814.4 g)

Gravel	Top Tray Gravel (≥ 2 mm)	Middle Tray Gravel Sludge (<2 mm and ≥0.074 mm)	Bottom Pan Gravel Silt and Fines (< 0.074 mm)
Wet gravel	1,735.0 g	148.4 g	63.3 g*
Dry gravel	1,640.5 g	104.6 g	63.3 g*
Amount of water	94.5 g	43.8 g	3,495.7 g*
% by weight solids	90.4	5.8	3.8
% by weight moisture	5.4	29.5	N/A
% by volume of water removed	2.6	1.2	N/A

* By mass balance.

Test for Cleaning Ability

We also studied how well wet screeningcould clean. We performed the wet screening operation described earlier several times using water and twice using a nitric acid solution (pH 2) on contaminated gravel. Samples of the gravel in the top tray, middle tray, and bottom pan were taken and analyzed. The test results for gravel washed with water are shown in Table 4.

The analyses shown in Table 4 are based on the State of California's leach test and total waste analysis. The differences between the Federal (TCLP) and the California State (STLC) leaching tests are subtle. The California State leaching test is more rigorous and, therefore, provides us with more conservative results. The differences in these tests are summarized in Table 5.

The STLC test was performed on the larger pieces of gravel (particles > 2.0 mm) to test the effectiveness for reducing leaching, and the TTLC test was performed on the sludge and silt (particles ≤ 2.0 mm) to determine the type and concentration of material that was removed by the screening process.

Table 4 shows that some beryllium, chromium, copper, lead, and zinc was removed; however, when performing a mass balance on each contaminant, the exact amounts or percentages could not be calculated with the limited number of samples taken. The gravel is heterogeneous, which made it difficult to collect representative samples. Future samples will be taken of the gravel, sludge, silt, and fines. These sampling results may help us determine how well wet screening cleans the gravel.

Table 4. Analysis of Gravel Washed with Water.

Contaminant	Unwashed Gravel		Gravel Washed with Water		
	Before Study		Top Tray Gravel > 2.00 mm	Middle Tray Sludge < 2 mm ≥ 0.074 mm	Bottom Pan Silt and Fines < 0.074 mm
Metal Analyzed	**TTLC (mg/kg)**	**STLC (mg/l)**	**STLC (mg/l)**	**TTLC (mg/kg)**	**TTLC (mg/kg)**
Antimony	ND (<10.0)	ND (<0.5)	ND	10.6	ND
Arsenic	ND (<50.0)	ND (<2.5)	ND	ND	ND
Barium	56.6	4.3	9.6	86.6	6.8
Beryllium	ND (<0.70)	0.057	0.085	23.4	0.48
Cadmium	ND (<1.0)	ND (<0.05)	ND	ND	ND
Chromium	10.5	0.12	ND (<0.1)	213	0.83
Cobalt	3.5	0.094	0.12	9.6	0.3
Copper	15.1	0.76	0.41	654	6.7
Lead	ND (<10.0)	ND (<0.5)	ND	43.2	2.5
Mercury	ND (<0.10)	ND (<0.002)	ND	ND	0.022
Molybdenum	ND (<2.0)	ND (<0.1)	ND	3.5	ND
Nickel	10.2	ND (<0.2)	ND	123	0.94
Selenium	ND (<25.0)	ND (<0.3)	ND	ND	ND
Silver	ND (<1.0)	ND (<0.05)	ND	ND	ND
Thallium	ND (<100)	ND (<5.0)	ND	ND	ND
Vanadium	12.9	0.22	ND	58.2	1.4
Zinc	19.1	0.99	1.8	75.7	3
Radioactivity	**pCi/g**		**pCi/g**	**pCi/g**	**pCi/g**
Gross Alpha	7.52		4.07	not measured	4,460
Gross Beta	24.9		17.4	not measured	3,670

ND means not detected.

Table 5. Leaching Test Comparison (Federal versus State).

Criterion	TCLP (Federal)	STLC (California)
Extraction Fluid Type	Acetate buffer	Citrate buffer
Approximate Extraction Fluid pH	5	5
Approximate Solids Diameter (Maximum)	0.01 m	0.002 m
Leaching Time	18 h	48 h
Extraction Fluid Weight Ratio	20:1	10:1

DESIGN REQUIREMENTS

The full-scale Gravel Reconditioning Unit was designed to meet the following criteria:

- A gravel process rate of approximately 5,443 kg (12,000 lb) in a 6-hour day or 907 kg/h (2,000 lb/h)
- Ability to feed gravel to the screener with a front-end loader if conveyors are not used
- Hopper loading minimized to 2–3 times a day [i.e., gravel capacity of between 1.2–1.8 m^3 (42–63 ft^3) if a hopper is used]
- Skid-mounted unit, transportable by a flatbed truck, so that it can be moved from one gravel pad to another
- Ability to withstand an outside environment and outdoor location
- Portable so that it can be operated in the field on the gravel pad at a distance of 30 m (100 ft) from any electrical or water source
- Easy to operate and requiring minimal set-up, operating, and shutdown effort
- No use of an air compressor in its operation
- LLNL seismic criteria at all times
- Design and fabrication cost of less than $100,000 for the unit
- Design, procurement, and fabrication schedule of 7 months

Design Overview

The Gravel Reconditioning Unit is a skid-mounted unit used to recondition gravel at Site 300. The reconditioned gravel is restored to its original size with its original dampening effectiveness and is placed back into use. The Gravel Reconditioning Unit contains a feed delivery system, screen separator unit, water reservoir, water recirculation system, rinsate separation system, and control panel. A schematic layout of the gravel reconditioning process, including the mass balance for the gravel and water, is shown in Figure 1.

Feed Delivery System

The feed delivery system contains a hopper, slide control valve, and flexible connector. The feed delivery system uses a front-end loader to place the gravel into the hopper. Because a front-end loader is used, the height of the hopper is restricted to less than 2.90 m (9.5 ft). The hopper feeds to the screen separator unit that is mounted on the skid. The screen separator requires a 0.15-m (0.5-ft) clearance above the unit to change out the screens. Given the height of the screen separator and the necessary clearance, the bottom of the hopper must be at least 1.90 m (6.25 ft) off the ground. In addition, for seismic considerations, the hopper needs to be as low to the ground as possible. For these reasons, the hopper was designed to be 2.72 m (8.92 ft) tall × 0.76 m (2.5 ft) deep, with a hopper bottom 1.96 m (6.42 ft) off the ground.

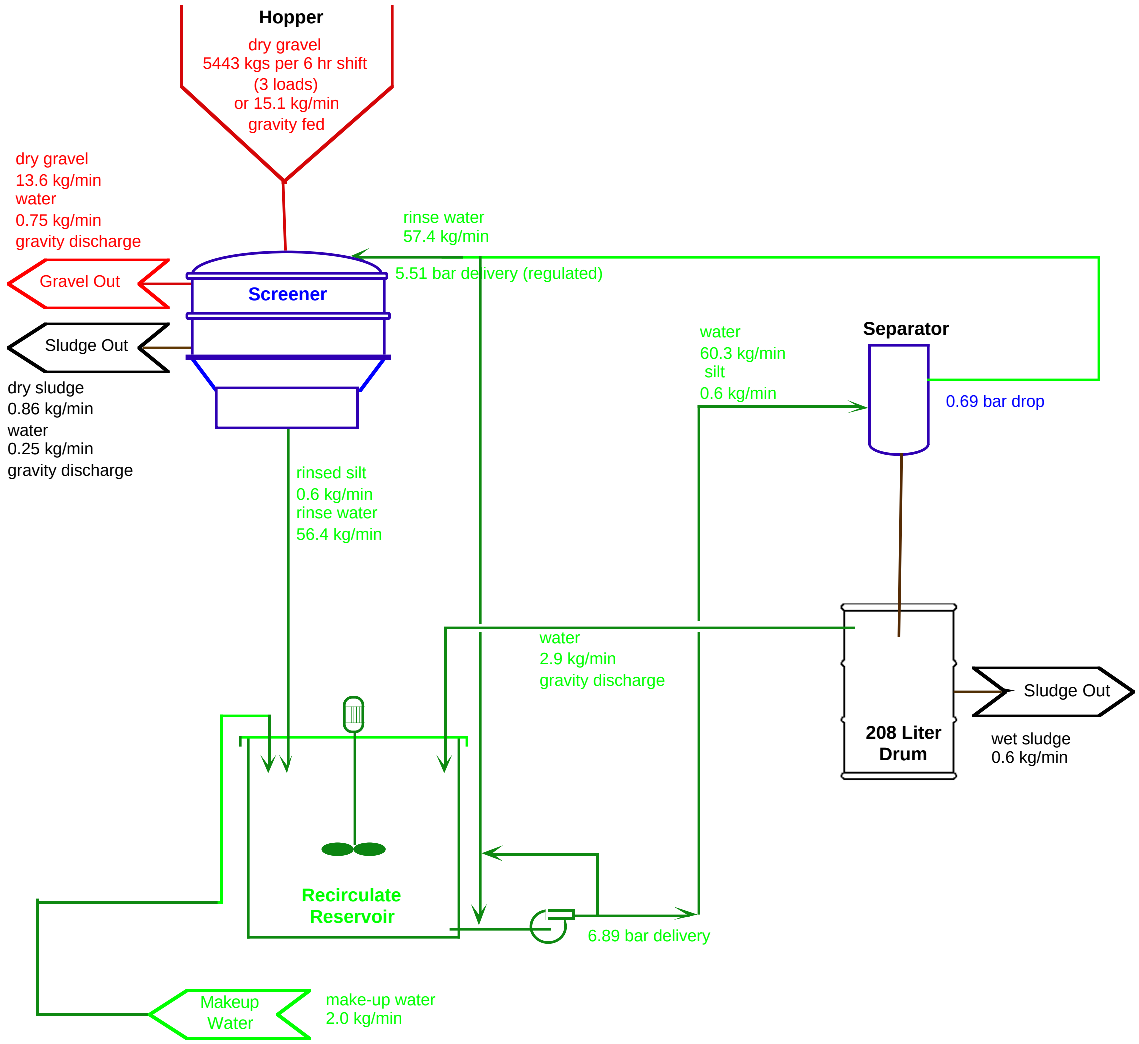

Figure 1. Gravel Reconditioning Process Schematic.

The angle of slide for the gravel was determined using Marks' *Standard Handbook for Mechanical Engineers*, which states that the angle of slide (i.e., the angle at which material will flow on an inclined surface) for stone is about 30° with the finer material being 35–40°. For stone, ore, and coal, it is customary to build chutes on a angle of 45°; however, by using a 45° angle of slide, the height of the hopper would have exceeded the maximum height by 20 cm (8 in.). Therefore, the slide angles for the hopper were determined by experiment. Gravel was piled on one end on a metal sheet. The gravel-end of the metal sheet was raised, and the height at which the gravel slid freely was measured. From the height and the length of the metal sheet, the angle of slide was calculated. This experiment was repeated several times, and the calculated angles ranged from 26° to 27.5°; therefore, we determined that 30° would be an acceptable minimum slide angle for the hopper.

For ease in construction, the hopper was designed as an inverted pyramid with a rectangular opening and base. The hopper was designed with the top opening 2.44 m long and 1.67 m wide (8 ft × 5.5 ft) and is tapered down to a square opening at the bottom 0.30 m long and 0.30 m wide (1 ft × 1 ft). The side angles of the hopper are 41.9°, while the end angles are 30°. The capacity of the hopper is 1.6 m^3 (55 ft^3).

The hopper could be constructed of either aluminum or stainless steel because neither one of these materials deposit contaminants on the gravel. Aluminum is less expensive and lighter in weight (i.e., ideal for seismic considerations since the center of gravity is lower); however, the material is soft and may dent or erode with the addition of gravel. Aluminum is also difficult to weld and, at LLNL, the time and staff to fabricate the hopper out of aluminum is greater than for stainless steel. For these reasons, the hopper was constructed out of 304 stainless steel with all exposed seams welded.

Structural steel is used to support the hopper. Each corner of the hopper is supported by 15.2 cm × 15.2 cm × 0.63 cm (6 in. × 6 in. × 1/4 in.) box tubing. To maintain seismic stability, outriggers, hinged at the corners of the hopper support structure and pinned in place, are used when the hopper is loaded. The overall dimensions of the Gravel Reconditioning Unit, without the extension of the outriggers, is 1.7 m wide × 2.4 m long × 2.7 m high (5.5 ft × 8 ft × 8.9 ft). With the extension of the outriggers, the length and width are both increased by 1.4 m (4.7 ft).

The bottom opening of the hopper is located directly over the inlet to the screen separator unit. The slide control valve is mounted under the hopper and regulates the amount of gravel entering the screen separator unit. The slide control valve is a manually operated slide valve with an aluminum body and a steel slide plate. With a little effort, the manual valve can be shut against a full hopper of gravel.

The flexible connector is mounted at the bottom of the slide valve and is connected to the screen separator unit. The flexible connector is constructed out of neoprene. The connector is flexible so that it can move with the screen separator when it vibrates and can be lifted off easily to change out screens.

Screen Separator Unit

The screen separator for the Gravel Reconditioning Unit is a commercial unit used for wet classification (i.e., solid classification in a liquid medium). The screen separator is cylindrical, has a screen diameter of 0.76 m (30 in.), is 1.06 m (42 in.) tall, and is constructed out of stainless steel. The screen separator has two screens and antiblinding features to dislodge small particles from the screen. The sieve mesh for the screens are No. 10 mesh and No. 200 mesh, but additional sieve mesh sizes are available.

The screen separator has one inlet at the top of the screen separator, three discharge ports, and a spray system. To prevent incoming gravel from damaging the screen, a velocity breaker (strike plate) was installed on the screener lid. The top discharge port is for effluent gravel (particles > 2 mm), the middle discharge port is for effluent sludge (particles ≤ 2 mm and > 0.074 mm), and the bottom discharge port is for the effluent silt, fines, and water. The top and middle discharge ports were extended to 1.02 m (40 in.) to reach past the skid. To prevent gravel or sludge from blocking the outlet, a 20° slant was provided on the extended discharge ports. A spray system was also designed for this unit using six nonclog spray nozzles that wash the gravel as it vibrates on the top screen. The nozzles are designed for a maximum flow rate of 60.5 L/min (16 gpm) and a pressure of 5.515 bars (80 psi).

The screen separator uses a three-dimensional inertial vibratory motion to separate particles by size. The screen separator vibrates horizontally, vertically, and tangentially. The control for gravel flow in the unit is adjustable by increasing and/or decreasing the mass of the top and bottom eccentric weights and the increasing or decreasing the lead angle of the bottom eccentric weight. Increasing the bottom eccentric weight increases the vertical component of motion, increasing the top eccentric weight increases the horizontal throw and cause oversized material to discharge at a faster rate, and increasing the lead angle of the bottom eccentric weight imparts a spiral motion of the particles on the screen. If gravel requires additional cleaning, the lead angle of the bottom eccentric weight is increased to keep the gravel on the screen longer.

The screener separator is mounted on a stand to the skid. The height at which the screener separator was mounted to the skid was critical because it affects the overall height of the hopper. The height of the discharge ports determined how high to raise the screener separator. The height of the top discharge port (gravel spout) was designed to be high enough so that the bucket of the front-end loader can be positioned under the spout to collect clean gravel or to facilitate placement of approximately 1.56 m^3 (55 ft^3) of gravel on the ground. The height of the middle discharge port (sludge spout) is high enough above the ground so that a 208-L (55-gal) drum, 0.89 m (35 in.) tall, can be placed under the spout.

Water Reservoir

The silt, fines, and water out of the bottom discharge flows into a water reservoir that is constructed out of stainless steel, has a total capacity of 566 L (150 gal), and an average operating volume of 330 L (87 gal). Makeup water is also introduced in the water reservoir. The discharge for the silt solution is at the bottom of the water reservoir. A hinged lid is mounted on top of the reservoir for easy cleanout.

A mixer and instrumentation for monitoring pH, conductivity, high water level, low water level, and high-high water level are mounted to the water reservoir. The mixer is located on top of the water reservoir and uses a 1/3 horsepower motor and a 5.1-cm (2-in.) turbine blade to agitate the contents. A pH probe and conductivity probe are mounted inside the water reservoir and monitor the conditions of the solution. High water level, low water level, and high-high water level sensors are mounted in the water reservoir. When the water level is below the low water level, an alarm is activated and indicates that the system is low and makeup water is required. The makeup water continues to fill into the system until the high water level indication is reached. When the water level reaches the high water level, the makeup water is automatically shut off. If the water level reaches the high-high water level, an alarm is activated and indicates that the system is near overflow (85% of total capacity).

Water Recirculation System

The water recirculation system consists of a pump, valves, and piping. The system is designed to process the reservoir water through the rinsate separation system and recirculate it back into the screener separator. The system was designed to the maximum flow rate and pressure requirements of the spray nozzles. The water recirculation system is designed to provide a flow rate of 60.5 L/min (16 gpm) and a pressure of 5.515 bars (80 psi) at the spray nozzles. At the designed pressure and flow rate, there is a 1.4–1.7 bar (20–25 psi) drop across the system due to friction losses. Therefore, the pump is designed to operate at 60.5 L/min (16 gpm) and at a pressure of 6.9–7.3 bars (100–105 psi). The pump is also designed so that it doesn't pulsate because pulsating flows cause interferences with the rinsate separation process. The pump chosen is a multistage centrifugal pump that operates at 60.5 L/min (16 gpm) at 7.0 bars (102 psi).

The valves and piping are designed to meet high system working pressures and constructed out of material that is protected against outdoor environments (ultraviolet radiation). The valves and piping used is chlorinated polyvinyl chloride (CPVC), schedule 80, and designed for a maximum working pressure of 47.6 bars (690 psi) at 23°C (73.4°F).

In addition to the valves that direct and regulate flow, an overpressure relief valve and pump bypass valve was installed to prevent over pressuring the system. A flow meter was also installed on the water recirculation line to monitor the flow rate of the recirculated water.

Rinsate Separation System

The rinsate separation system consists of a hydrocyclone separator, motor-operated ball valve, purge diffuser, and drum decant system. The rinsate separation system is installed in the water recirculation system to remove silt and fines from the recirculated water. The solid-free water is discharged out the top of the hydrocyclone separator and into the screen separator. The solids are discharged out the bottom of the hydrocyclone separator and into a 208-L (55-gal) drum. Liquid from the 208-L (55-gal) drum is decanted off and gravity fed into the water reservoir.

The solution pumped from the water reservoir enters the hydrocyclone separator tangentially, which sets up a circular flow. The solution is then drawn through tangential slots and accelerated into the separation chamber of the hydrocyclone separator. Centrifugal action tosses particles heavier than the water to the perimeter of the separation chamber. The particles drop along the perimeter of the cyclone separator and settle into the collection chamber. The solid-free water is drawn up the separator's vortex, up through the separator's outlet, and into the screen separator.

For particles with a specific gravity of 2.6, the hydrocyclone separator is designed to remove approximately 95% of particle greater than 0.074 mm, 75% of particle between 0.040 mm and 0.074 mm, and 40% of particles between 0.020 mm and 0.040 mm. In recirculated systems, the hydrocyclone separator is designed to remove 98% of particle greater than 0.074 mm, 93% of particle between 0.040 mm and 0.074 mm, and 65% of particles between 0.020 mm and 0.040 mm.

The solids remain in the hydrocyclone separator until approximately 1.2 L (0.3 gal) of solids has been collected. When the collection chamber is full, the motor-operated ball valve opens and the contents discharge into a 208-L (55-gal) drum located underneath the cyclone separator. Due to high system pressures, a purge diffuser was installed on the hydrocyclone separator discharge line to prevent inadvertent spraying of liquid. Approximately 7 parts liquid to 1 part solid is ejected each time the cyclone separator is purged.

The drum decant system, which consists of a drum shroud with baffle plate and a discharge line to the water reservoir, is attached to the 208-L (55-gal) drum. The gasketed drum shroud is clamped to the top of the drum and allows the water level to raise past the height of the drum without leaking out. As the discharged material (solids and water) fill the 208-L (55-gal) drum, the solid material tends to settle to the bottom of the container while the lighter material remains on the top. When the water reaches the discharge port, the water gravity flows into the water reservoir. The drum decant system minimizes the amount of makeup water to be added to the system, minimizes the amount of liquid waste to treat, and maximizes the solid holding capacity in the drum.

Control Panel

All controls for the Gravel Reconditioning Unit are located on a control panel (see Figure 2 for a layout of the control panel). The frequency and duration for purging the hydro-cyclone separator are also adjustable from within the panel. The panel is a NEMA 4 enclosure, and all controls are weather resistant and rated for outdoor use. The lights and controls on the control panel are visible from outside the enclosure. A crash button and main disconnect are also mounted on the control panel. A 38.1-m (125-ft) grounded cable with connections to a 208-V, 20-A receptacle provides the power for the screen separator, pump, mixer, and miscellaneous controller. The power cable is routed to the back of the control panel.

CONCLUSIONS

The Gravel Reconditioning Unit was designed and fabricated in 8 months for less than $100,000. Testing began in January 1995. Preliminary results proved acceptable for clean pea gravel. Further testing will be on the contaminated gravel at Site 300.

During testing, the clean gravel was loaded into the hopper by a front-end loader in less than 5 minutes. No spillage was noted when loading the gravel. With a little effort, the slide control valve under the hopper could be opened and closed against a 0.84-m (33-in.) head of gravel. The flow rate of gravel was regulated by slide control valve. Gravel entered the screener separator easily, and the velocity breaker prevented the gravel from damaging the top screen of the screener separator. Water from the spray nozzles removed a majority of the silt and fines from the gravel. The gravel discharged out of the top tray was considerably silt-free and greater than 2 mm in size.

The particles smaller than 2 mm entered the middle screen. A majority of the larger sludge particles came out the middle discharge port. When the middle screen became clogged, unexpected water came out with the sludge and emptied into the drum. This problem is being corrected by using a screen with larger openings and providing a modified drum decant system on the sludge drum to return excess water to the water reservoir.

The remaining water and silt (particles $< 74\ \mu m$) in the screener separator was discharged into the water reservoir. The mixer adequately kept the silt in solution. The centrifugal pump was able to pump the silt solution up through the hydrocyclone separator and to the screener separator. At the specified frequency and duration, the hydrocyclone separator discharged the silt into the drum decant system. The excess liquid in the drum decant system successfully flowed into the water reservoir.

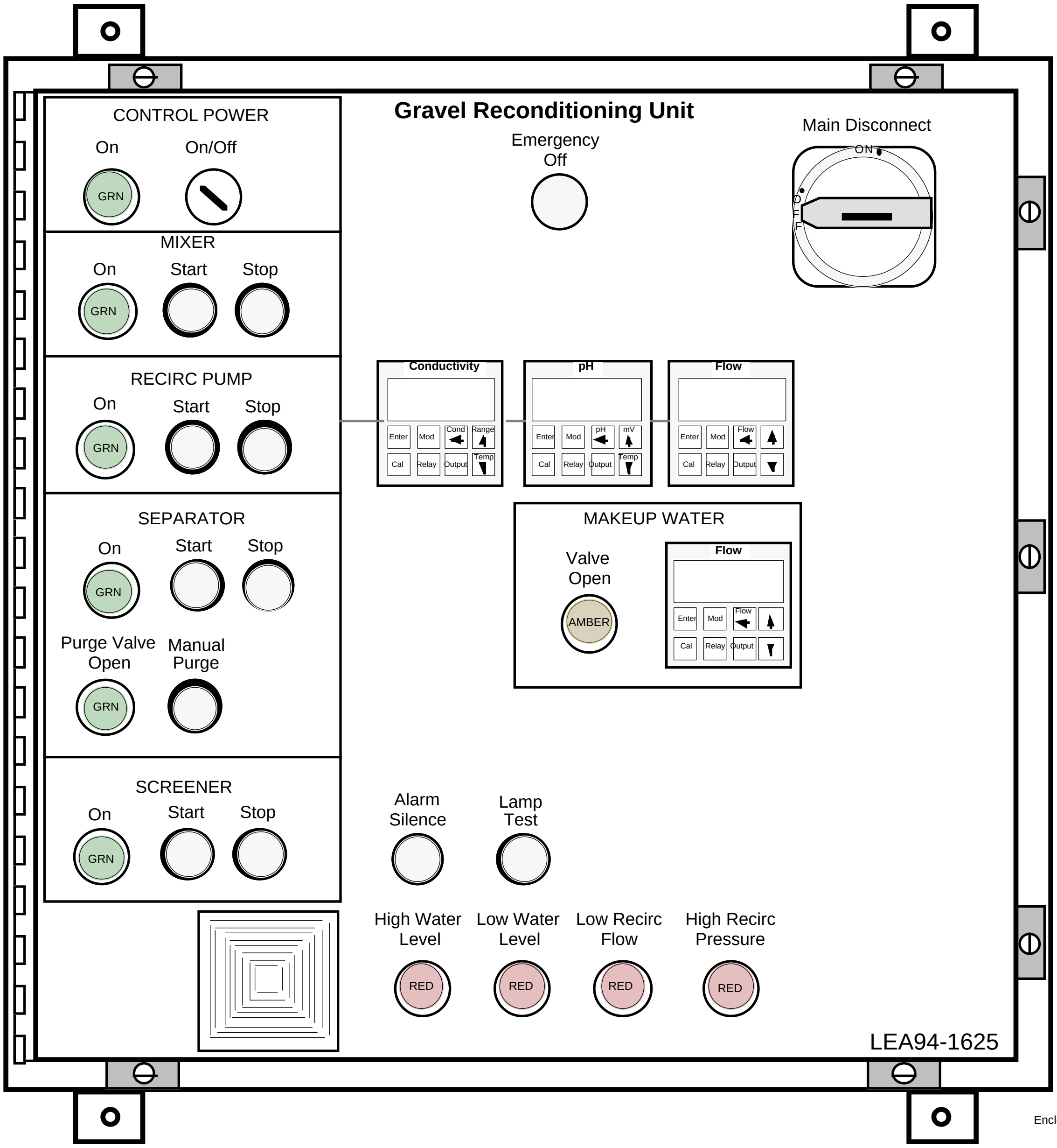

Figure 2. Layout of the Control Panel.

The handling and treatment of the waste water generated by the reconditioning process is a routine practice for LLNL. The waste water can be treated at the Tank Farm and (when analytical results indicate that it meets acceptance criteria) emptied into the LLNL sewer (ultimately to reach the city water reclamation plant). The silt and sludge waste generated by the reconditioning process can also be treated at LLNL. The silt and sludge will be stabilized in their container.

The Gravel Reconditioning Unit is an inexpensive, easy-to-use, low maintenance, portable, and effective way to recondition gravel. Applying the Gravel Reconditioning technique to the gravel on the gravel pads at Site 300 will reduce the amount of low-level radioactive waste, low-level radioactive waste with California hazardous metals, or RCRA mixed waste generated. In an 8-h period approximately 5,443 kg of gravel will be processed with up to 90% by weight (or 4,899 kg) of the large gravel being recycled. This procedure results in a cost benefit of up to $1,800/day savings in disposal costs and additional savings in costs associated with the procurement and delivery of new gravel.

REFERENCE

1. *Standard Handbook for Mechanical Engineers*, Eighth Edition. Published by McGraw Hill Book Company (1978).

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